THE VANCOUVER AMATEUR DIGITAL COMMUNICATIONS GROUP

by Doug Lockhart, VE7APU

Since the initial publication of the information on the activities of the VADCG about five months ago, I have received a number of inquiries and questions. This feedback indicates a few areas of misunderstanding which I will try to address here as well as update on more recent developments.

Firstly, the previously published information only describes the frame level protocol that was written at the time of publication. In fact it does not even describe the frame level (link level) protocol in any detail. This was done because of space and time considerations and because of the intended audience for the article. The intended audience was the average amateur with little or no knowledge of digital communications protocols. We in the VADCG are aware of the different levels of protocols required for an extensive amateur radio communications network and are nearing completion of the design of the necessary higher level protocols.

Several have expressed concern about having to rely on a special station node in the network in order to communicate. For example, repeaters are in common use on the VHF bands but hams can still make 'simplex' contacts if they choose or if their repeater is down for repairs. The VADCG is addressing this concern by writing software for the terminal node controllers which will allow communication between terminals directly. It provides most of the important features as are provided in the 'station-controlled' network such as; the establishment and termination of virtual connections, channel sharing among a large group of users, data integrity, and flow control at the data link level. Although not supplying the additional features available when operating in a station-controlled network, it will be useful in situations where propagation conditions allow direct communication and in areas where there is no station node in operation yet.

The station node software described in the previous newsletter has been debugged and is in operation here in the local network in Vancouver. The LIP (link interface program) is operational as well and several simple TIP (terminal interface program) programs have been written to interface various terminal equipment for the local users. We are working at adding new functions to these programs as well as optimizing some of the network parameters in both software and hardware.

The first run of 25 PC boards has been sold out and we will shortly be getting another run made up. We have assembled a few complete sets of parts for the board as a service for those who do not want to be bothered obtaining the parts on their own.

For those interested in learning more about the VADCG's packet radio activities, our hardware and software and future plans, then please write to the following address:

1262 Balfour Avenue, Vancouver, B.C. V6H 1X6

The following paper was written by Peter Driessen, VE7BBQ. It gives an outline of the different levels of protocols required and it agrees fairly closely with our ideas in the VADCG even though the actual development of the VADCG system was less influenced by HDLC and X-25 protocols than this paper might imply. Please bear in mind that it was written about a year ago. The paper does not mention level IV protocols. These are the user-to-user protocols connecting processes on an end-to-end level. We believe that these protocols have to be implemented as well as protocol levels I to III. These higher level protocols become more and more necessary as the number of users and geographic extent of the network increases.

June 26, 1980

DESIGN OF AN EXPERIMENTAL PACKET RADIO NETWORK FOR PERSONAL AND HOBBY USE

by Peter Driessen, VE7BBQ

"The convergence of personal computing and citizens radio should not take much time to spawn a new sociological phenomenon." [1]

The advent of low cost microcomputers combined with the availability of spectrum space to Radio Amateurs inevitably leads to the combination of these two hobbys in the form of computer- communications. The Canadian Department of Communications has acted as a catalyst in this regard by creating a new "Digital" class of Amateur Radio licence which can be obtained by demonstrating knowledge of data communications. Computer hobbyists can thus gain access to parts of the radio spectrum and create a data communications network for personal and hobby use. In fact, the preliminary design of such a network is presently underway in both Vancouver and Montreal.

Eventually the technology thus developed may lead to the creation of a data communications "citizens band" available to the general lay public. The ubiquity of the present voice citizens band with many millions of users indicates that such a data communications citizens band might well be of significant interest.

The potential application of personal data communications in todays society are many and varied, but will not be addressed here. The subject of this paper is to describe some of the background and preliminary design of a computer-communications network using radio links which can be implemented by Radio Amateurs and computer hobbyists for their personal use.

Packet switching is a highly efficient way of using radio channels for computer communcations where there is a potentially very large number of users. Thus the creation of a packet radio network is the natural way to combine activities of Radio Amateurs and computer hobbyists. Two important aspects of the proposed packet radio network need to be decided upon: the protocols and the modulation schemes.

The proposed packet radio network will initially consist of a number of user terminals in one metropolitan area (eg Vancouver) connected to each other via a repeater located on a mountaintop or other favorable radio location. The location and quality of the repeater will govern the maximum geographical extent of the initial network; it will typically be about a 100 km radius for users in fixed locations with directional antennas. Any terminal located within the coverage area of the repeater can communicatie with any other terminal in the area. No routing or flow control will be required. Access to the network will use the ALOHA random access technique.

The initial network will operate at relatively low speeds

in the Amateur 144-148 MHz band using existing voice channels. Later , a high speed access to the network will be added , using wideband channels available in the Amateur 220-225 MHz band.

The desire to communicate beyond the 100 km coverage area of the repeater will lead to the establishment of multiple repeaters connected vial terrestrial or possibly satellite links. Stations will be required to control the network and establish virtual connections.

PROTOCOLS

Communications protocols are required to ensure an orderly exchange of information betwen two or more parties. A protocol defines the rules for the operation of a communications link and manages the flow of information over the link.

Protocols function at different levels in order to control different aspects of communication within a network. Level I defines the nature of the physical link between the data terminal equipment (computer or terminal) and the data-circuit terminating equipment (modem). Level II is the data link control which provides control between two nodes (terminals) in a network. It provides the envelope in which information is transferred from node to node. Level III is the path control which defines the procedures for establishing virtual connections in a network. Its functions include routing, flow control, and end-to-end acknowledgement of receipt of a packet.

In the design of the Amateur packet radio network existing standards for these protocols will be used as much as possible for reasons of ease of implementation and hardware availability. Non-standard protocols will only be used if the standards are unsuitable or non-existent. In the following sections, details of the various protocol levels will be described.

Level I protocols provide the handshaking operations between terminals (or computers) and the modem. This protocol has been standardized in North America as the EIA RS-232C interface. This 25 pin interface serves four main types of function: electrical ground, data exchange, control and timing. The data is exchanged through the interface as a serial bit stream.

The control functions include: request to send, clear to send, data set ready, data terminal ready, received line signal detector, and data signal rate selector. Timing pulses are passed for both transmitted and received data. This interface appears to be suitable and will be used in the Amateur packet radio network.

The level II protocol is the data link control which manages the information flow on the link. Data link control functions include framing, link management, and error checking.

It must also be transparent to the data. Framing the message block locates the start and end of each message. Link management consists of deciding who may transmit when and establishing and terminating a link connection. Error control is done by adding error detection codes to the mesages before transmitting and checking the codes on receive. The International Standards Organization has adopted a reasonably efficient, reliable and easy-to-implement level II protocol standard called High-level Data Link Control (HDLC). HDLC is a bit-oriented protocol in which the position of the data in a frame defines its meaning. An HDLC frame consists of an address field, control field, information field, and frame check sequence. It is bounded at each end by a flag (Fig.1.)

Older protocols such as IBMs Bisync were character-oriented in which special control characters were used to define the meaning of data. Bit-oriented protocols are superior to character-oriented ones because they have higher throughput (no control character overhead), are simpler to implement and do not require any software for interpretation of control characters.

The HDLC frame need not be rigidly fixed as in Fig. 1. The address field may be extended beyond its basic 8 bit length. If the first bit of an address byte is zero, then the next byte is an extension of the address field. The last address byte in the field would begin with a 1. This ability to extend the address field is very useful to accommodate expansion of the network.

The control field is used for encoding commands and responses required to control the data link. There are three types: supervisory, used to convey ready or busy condition; information transfer, used to send sequenced (numbered) information frames; and nonsequenced, for data link management.

The frame check sequence provides error detection. It performs a cyclic redundancy check on the entire frame . The address, control, information and FCS fields represented by binary numbers $a_{k-1} a_{k-2} \cdots a_2 a_1 a_0$. are interpreted as a polynomial $a_{k-1} x^{k-1} + a_{k-2} x^{k-2} + \cdots + a_1 x + a_0$. (FCS set to all-1s). This polynomial is then multiplied by x^{16} and divided by the CCITT standard CRC polynomial $x^{16} + x^{12} + x^5 + 1$ . . The complement of the remainder of this division (x^{15} through x^0) is then transmitted in the FCS field. The recieving station performs a similar calculation on each complete frame (including the FCS as received, not set to all-1s). If there are no errors, it can be shown that the receivers calculated FCS should equal F0B8 hexadecimal.

Only three bit sequences have special meaning in HDLC : the flag sequence 01111110 which is transmitted at the beginning and end of each frame, the abort character (7 to 14 consecutive 1s) which is sent if there is a problem at the transmitter end, and an idle state (15 or more consecutive 1s).

Information transparency requires that none of these special bit sequences be accidentally transmitted in the data

fields of a frame. To ensure this, bit stuffing is used, where a 0 bit is inserted whenever five successive 1s are transmitted in the data. The reciever counts the number of 1s and deletes the 6th bit if it is a zero following five 1s. Should the 6th bit be a 1 followed by a zero, a flag is detected. Should the 6th bit be a 1 followed by another 1, the frame is aborted. Thus bit stuffing prevents the chance transmission of a flag, abort, or idle character in the data field.

A non-return-to-zero-inverted (NRZI) coding scheme can be chosen as an optional feature for use on aynchronous data links. NRZI coding specifies that the signal condition (high or low) does not change when a binary 1 is encountered in the data stream, while a binary 0 causes a change of state. Thus a line transition is guaranteed within the time it takes to send 6 bits (because of bit stuffing) and the clock can be derived from the received data. The need for a separate clock is eliminated. This scheme will probably be used for the low speed asynchronous links in the network.

Both HDLC and IBMs Synchronous Data Link Control (SDLC) are bit-oriented protocols which employ the same basic format, special bit patterns (flag, abort, idle) and error checking. HDLC is preferred over SDLC for the Amateur packet radio network for several reasons. HDLC supports a recursive extension of the address field which SDLC does not. HDLC can request retransmission of a single information frame, while acknowledging previous frames (selective ARQ). SDLC can only use go-back-N or stop-and-wait ARQ. HDLC has a greater number of nonsequenced control commands and responses. The information field in HDLC can be any length, whereas in SDLC it must be a multiple of 8 bits. HDLC supports a balanced link configuration where both ends of the link are equal, whereas SDLC retains centralized control with one primary and a number of secondary stations.

The requirements for a level II data link management protocol as outlined above might be considered beyond the capability of computer hobbyists and Radio Amateurs. However, a number of conpanies currently market data link control chips, which perform many of the level II protocol functions. The requirements of bit stuffing, generation and recognition of flag, abort, and idle sequences, and full duplex generation and detection of CRC codes are all implemented in hardware on the data link control chip. The easy availability of such complex chips is one of the major breakthroughs which allows a sophisticated network to be developed for personal and hobby use.

It is proposed to design a programmable communications interface for access to the network using a data link control chip and microprocessor. This interface will connect the user terminal to the modem and radio transceiver, and will perform all of the level II protocol operations using HDLC. Data to be sent is entered via the user terminal. A small program on a separate EPROM will be needed to acommodate the characteristics

of the particular terminal, ie its speed, code (EBCDIC, ASCII, or Baudot), and whether or not it is buffered. The CPU also processes the control field of the HDLC frame. The data link control chip takes the data from the CPU and creates the HDLC frame to be transmitted, or restores the data from a received HDLC frame and passes it to the CPU.

Level III protocols provide routing, flow control and end-to-end acknowledgement of a packet. This packet level protocol effects the setup, use, termination , flow and error control of virtual circuits between two terminals. In the initial stages of development of the Amateur packet radio network, routing and flow control will not be required because of the broadcast nature of the network within a local area. Only if communiciations are desired between points not directly linked by a single repeater is some kind of routing and flow control essential. Intelligent stations will need to be established to perform level III protocol operations. Terminals will not have this capability.

Routing information can be dispersed by a station in three ways: to repeaters,in which case only source/destination information need be included in the HDLC frame; to the receiving terminal, in which case all routing information must be included in the address; and to the originating terminal which then transmits a route setup packet to create routing entries in the repeaters, thus setting up a virtual circuit.

Flow control can be as simple as stop-and-go, in which the receiver either accepts or rejects all traffic. This method is common also at the data link control level, is simple to implement, and satisfactory on terrestrial links. On satellite links the propagation delays are too long, and some traffic still flows until the stop message actually arrives at the sender, and likewise the circuit will be idle until the go signal arrives. A permit or credit system of flow control avoids these problems, but is much more complex to implement.

The CCITT X.25 level II protocol is an international standard for packet-switched communications. It also incorporates HDLC at level II and X.21 (similar to EIA RS232C) at level I. The X.25 protocol establishes virtual circuits with call request packets and receives call confirmation packets in return. These virtual circuits carry packets in sequence from source to destination. Permanent virtual circuits may also be set up. However, X.25 does not have a mechanism for end-to-end acknowledgement of packets, so that this must be supplied externally.

Development of suitable level III protocols for the Amateur packet radio network can be approached in several ways as outlined above. The X.25 protocol, or some subset thereof, is a likely choice if for no other reason then that it is an international standard.

MODULATION SCHEMES

A modulation scheme which is simple to implement with easily available equipment will be required to get maximum participation in the Amateur packet radio network. FM voice transceivers operating in the Amateur 144-148 MHz band are widely available, and most Amateurs already own one. Thus it is proposed to use AFSK for the low speed links of the network. Two audio tones, representing either a binary 0 or 1, are used to modulate a conventional FM voice transceiver operating on existing FM voice channels. This is type F2 emission as defined by the International Telecommunications Union. The modulating signal is equivalent to an FSK signal with a carrier frequency in the audio band. This modulation scheme is easy to implement because both AFSK generators and FM voice transceivers are readily available and do not need to be modified. However, it is not very efficient in terms of data rate vs bandwidth.

The modulation scheme chosen for the high speed links utilizing wideband channels in the Amateur 220-225 MHz band will depend strongly on the availability of low cost equipment. Highly efficient use of the bandwidth is not a primary consideration at this time and will be traded off against low cost.

Modulation schemes chosen for the proposed land mobile digital communications in the 800-900 MHz band will no coubt affect the choice for the Amateur packet radio network. Digital communications equipment manufactured for land mobile may soon be readily available and can probably be easily adapted for Amateur use.

The spectral emission constraints for Amateur Radio are considerably relaxed compared to those of other radio services. Regulations governing the available bandwidth per channel are still preliminary and subject to change. Traditionally, Radio Amateurs have been allowed to develop their own channel plans within the Amateur bands without government regulation.

SUMMARY

> "The Department of Communications wishes to encourage Canadians to be come proficient in communications and computing technologies and, in particular, in the organization of radio and computing equipment for accomplishing resource sharing in man to machine and machine to machine networks"

Dr. John DeMercado, Director General, Telecom Regs, 16 September 1978

A packet radio network for personal and hobby use is presently under development by Radio Amateurs and computer hobbyists in Vancouver and Montreal.

The level II data link protocol chosen for the network is the international standard HDLC. A communications controller using a microprocessor and a data link control chip is presently being designed. The level III protocols will evolve as the network grows and its functions and applications are more clearly defined, but will probably be based on a subset of the CCITT X.25 protocol for packet switched networks.

The modulation scheme on the low speed,NRZI-encoded links will be AFSK modulating an FM voice transceiver for reasons of simplicity. Higher speed links utilizing more efficient modulation schemes will be developed in the future.

The potential applications of this Amateur packet radio network are many and varied and limited only by the ingenuity of its users.

REFERENCES

[1] L.Pouzin, H.Zimmerman, "A Tutorial on Protocols", Proc.IEEE v.66 #1 Nov.1978, pp.1346-1370

[2] V.G.Cerf, P.T.Kirstein, "Issues in Packet Radio Interconnection" Proc.IEEE, v.66 #1, Nov.1978, pp.1386-1408

[3] A.J.Weissberger, "Data Link Control Chips: Bringing Order to Data Protocols", Electronics v.51 #12, 8 June 1978, pp.104-112

[4] B.Meronek "Data Link Control Chip supports all three Bit-oriented Protocols", Electronics v.52 #2, 18 Jan 1979, pp.137-142

[5] IBM Synchronous Data Link Control, IBM Document # GA 27-3093-0 File # GENL-09, 1974

[6] ISO High Level Data Link Control- Elements of Procedure IS-4335, 1977

[7] R.W.Lucky, J.Salz, E.J.Weldon, "Principles of Data Communication" New York: McGraw Hill, 1968

[8] M.Schwartz, "Computer Communications Network Design and Analysis" New Jersey:Prentice Hall, 1977

[9] D.R.Doll "Data Communications", New York: Wiley, 1978